GEOL 333 - Lab 10 (Metamorphic Rocks in Hand Sample and Thin Section)

Introduction - Metamorphic rock forms from any pre-existing rock that undergoes changes due to intense heat and pressure without melting. There are 2 types of metamorphic environments: regional and contact metamorphism. **Regional metamorphism** affects large areas (thousands of square kilometers) and occurs deep within Earth, e.g., beneath mountain belts of convergent plate boundaries and at continent-continent collision zones. **Contact metamorphism** involves relatively localized, intense heating of rock surrounding an igneous intrusion. The most important changes to the rock that occur with increasing metamorphic grade (increasing temperature and pressure) are: (a) growth of existing minerals into larger crystals by recrystallization, (b) formation of new minerals and loss of old minerals and (c) development of **foliation** (arrangement of minerals in parallel or nearly parallel planes) by both physical reorientation of existing platy (flat) minerals and formation of new platy, aligned mineral grains. Foliation develops due to directed pressure, i.e., pressure that is greater in one direction compared to other directions. Directed pressure occurs during regional metamorphism associated with mountain building and tectonic plate convergence. **Protolith** (or parent rock) is the pre-existing rock (sedimentary, igneous or metamorphic) from which the metamorphic rock formed.

Classification - Metamorphic rocks are divided into 2 groups: nonfoliated and foliated. **Nonfoliated metamorphic rocks** either form during regional metamorphism (with directed pressure) but they contain few to no platy minerals or form by contact metamorphism, which does not involve directed pressure. Mineral grains in nonfoliated metamorphic rocks usually have a similar size and interlocking texture, also found in most igneous rocks. Common nonfoliated metamorphic rocks include: **marble** (~pure calcite, protolith = limestone or dolostone), **quartzite** (~pure quartz, protolith = quartz sandstone), and greenstone and amphibolite (both form from mafic igneous rocks). An environmentally important nonfoliated metamorphic rock is serpentinite, which forms from ultramafic igneous rock and includes the world's major asbestos deposits. Hornfels forms from any protolith during contact metamorphism, which involves high temperatures but no directed pressure.

Foliated metamorphic rocks contain platy or linear minerals (most commonly micas, but also amphibole and other minerals) arranged in ~parallel planes, commonly with an interlocking texture. Four foliated metamorphic rocks (all commonly form from shale with increasing metamorphic grade) include slate, phyllite, schist, and gneiss. **Slate** contains fine-grained (microscopic) clay minerals and splits along ~perfect parallel planes, called **slaty cleavage**. Phyllite contains clay minerals, just barely visible to the eye, with a shiny, satin-like luster. **Schist** contains medium to coarse-grained mica with a roughly parallel arrangement, called **schistosity**. **Gneiss** (which forms from either shale or granite) has **compositional (gneissic) banding**, roughly parallel bands of different colored, coarse-grained minerals. For schist and gneiss, the rock names are preceded by the major minerals, e.g., quartz-muscovite schist.

New Descriptive Terms

Foliation - metamorphic rock texture from alignment of platy (flat) mineral grains in parallel or nearly parallel planes

Protolith - pre-existing rock (sedimentary, igneous or metamorphic) from which the metamorphic rock formed

Metamorphic Grade - temperature and pressure conditions of metamorphism

Slaty Cleavage - splits along ~perfect parallel planes; typical foliation in slate

Crenulation - wavy, small-scale folding visible in hand sample; foliation type often seen in phyllite and sometimes in schist

Schistosity - medium to coarse-grained mica with roughly parallel arrangement; typical foliation in schist

Compositional (**Gneissic**) **Banding** - roughly parallel bands of different colored, coarse-grained minerals; typical foliation in gneiss

Porphyroblastic Texture - large crystals (porphyroblasts) in fine-grained groundmass, similar to porphyritic texture in igneous rocks

Lab Exercise

1) Describe the 4 types of foliated metamorphic rocks. How can you tell them apart, and what are their relative metamorphic grades?

2) In terms of texture, how are nonfoliated metamorphic rocks similar to igneous rocks? With this similar texture, how can you distinguish a nonfoliated metamorphic rock from an igneous rock?

3) Complete an Unknown Rock Identification Sheet (found at the end of this document) for each of the following 4 metamorphic rocks:

   a) 5M
   b) 9073
   c) L404
   d) L387

Unknown Rock Identification Sheets – Explanation of Terms

For the 4 metamorphic rocks assigned today, fill out an identification sheet that includes your observations on both hand sample and associated thin section. These observations are key to naming the sample, however the most important part is an accurate description of the mineral content and texture. Normally, the more information you collect and record about the sample, the better.

- **Rock Texture**

Rock texture refers to the size, shape and arrangement of the mineral grains. In your rock descriptions, use appropriate mineralogical terms for texture given in several lists below. Examples of questions to address include: Are grains preferentially aligned or randomly aligned? What is the average grain shape? Are the grains similar in shape or is there a wide range? What is the average grain size? Are most minerals the same size, two groups of sizes (such as in a porphyroblastic texture) or a wide range of sizes? Is shape similar for all mineral grains?

- Grain Size

Determine the average grain size (in mm) of the rock overall.

Field of View Size for our Petrographic Microscopes (used for grain size determination)

Power	**Width of field**	**Radius**
2.5x (low)	4.5 mm	2.25mm
10x (med.)	1.8mm	0.9mm
40x (high)	0.45mm	0.225mm

Grain Size Terms

Fine-grained – < 0.1 mm
Medium-grained - between 0.1 – 2 mm
Coarse-grained - > 2 mm

- Grain Contacts

Describe the grain contacts. **F** stands for floating grains (not touching), **T** = touching at small points, **L** = touching along long, straight contacts, **CC** = touching along long, concavo-convex (curved) contacts, and **S** = sutured contacts, typical of an interlocking texture.

- Foliation Type

Describe the type of foliation. List all of the following terms that apply: **Slaty cleavage, crenulation, schistosity, compositional (gneissic) banding, unfoliated**.

- Color

Describe the overall color of the rock.

- Sketch

Draw a representative sketch of the rock under low (2.5x) or medium power (10x) magnification. Make sure to label different minerals, circle the correct magnification and indicate whether the sketch is from plane-polarized light (PPL) or cross-polarized light (XP).

- Rock Name

Classify the rock based on your observations in hand sample and thin section. For schist and gneiss, list the major minerals before the rock name, e.g., quartz-muscovite schist.

- Metamorphic Conditions and Protolith

List the type of metamorphism (contact or regional), metamorphic grade, and a possible protolith for the rock.

Optical Characteristics of Minerals in Metamorphic Rocks
(bold font = diagnostic property used for identification)

Mineral Name (+ hand sample characteristics)	**Plane Polarized Light**	**Cross Polarized Light**
Quartz	Low Relief, **no cleavage**, **clear appearance**	**Low (1st order) birefringence** (white or gray)
Plagioclase Feldspar	Low relief, can be partly altered to clay (cloudy appearance)	**Polysynthetic twinning** (black and white stripes), Low (1st order) birefringence (white or gray), clay alteration involves small, highly birefringent grains
K-feldspar (characteristics in bold are most useful in distinguishing K-feldspar from quartz)	Low relief, **2 directions of cleavage (parallel lines) at 90° (moderately developed)**, can be partly altered to clay (cloudy appearance)	May show **Twinning** (**black and white criss-cross pattern**) and/or **exsolution lamellae** (**thin, parallel lines**), Low (1st order) birefringence (white or gray), clay alteration involves small, highly birefringent grains
Muscovite Mica	**1 perfect cleavage, clear**	High birefringence
Biotite Mica	**1 perfect cleavage, brown and pleochroic**	High birefringence
Garnet (New Mineral this week)	**Very high relief**, clear, often occurs as euhedral porphyroblast	**Isotropic** (completely black)
Calcite (**strong reaction with dilute acid**)	**High relief, perfect rhombohedral cleavage** (3 directions at 60° and 120°), **usually clear appearance**	Very high (>3rd order) birefringence (often appears white)
Dolomite (**weak reaction with dilute acid**)	**High relief, perfect rhombohedral cleavage** (3 directions at 60° and 120°), **commonly cloudy appearance**	Very high (>3rd order) birefringence (often appears white)

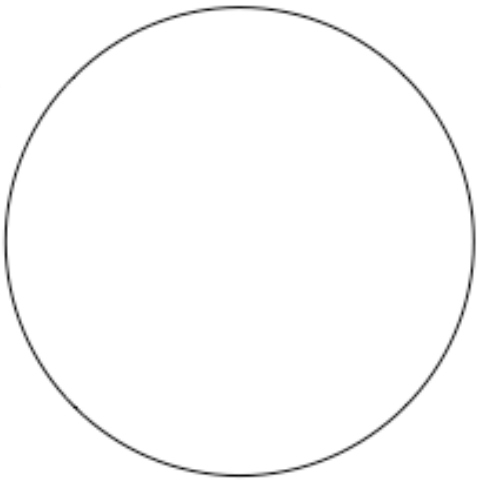
Be prepared to give your soil presentation in next week's Lab, April 4!

Metamorphic Rock Indentification (Lab 11)

Sample # **5M** Name:_____

1. Is this sample **foliated** or **non-foliated**? If foliated, is it a **slate**, **phyllite**, **schist**, or **gneiss**? **[0.2 pts]**

Thin Section Sketch (Color)
PPL / XP
Label Grains **[0.25 pts]**



2. The grains of the dominant mineral in this sample have abundant lineations. What are these lineations? What has happened to these lineations? [Hint: Are they perfectly straight?} What could have happened to the rock to cause this? Make sure to include this feature in your sketch. **[0.2 pts]**

3. **Complete the following table**. These should consider both hand sample (hs) and thin section observations (they should be pretty consistent, especially relative size and abundance).
The abundance must equal 100% for all listed species. **[1.0 pt]**

	Mineral 1	Mineral 2	Mineral 3	Mineral 4	Mineral 5	Mineral 6
Name						
Size						
Other Observaions						
Color & Form in HS						
Abundance (%)						

4. Did this rock undergo regional or contact metamorphism? Why? **[0.2 pts]**

5. What are likely protoliths for this rock (there can be more than one)? Why? **[0.2 pts]**

6. Rock Name: _____ **[0.2 pts]**

2.25 points

Metamorphic Rock Identification (Lab 11)

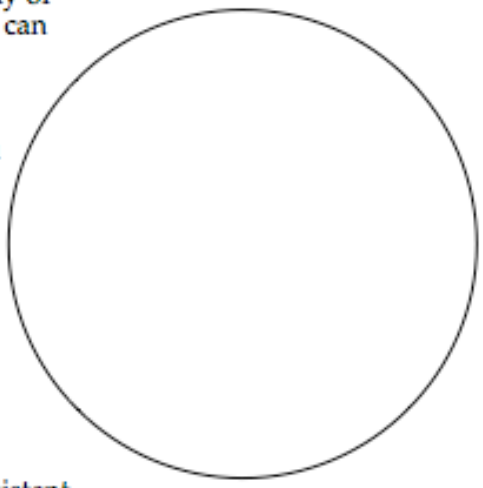
Sample # **9073** Name:_____

1. Is this sample **foliated** or **non-foliated**? If foliated, is it a **slate**, **phyllite**, **schist**, or **gneiss**? **[0.2 pts]**

2. Note the pleochroic mineral in plain light. Is this mineral randomly or preferentially aligned? What observations can you make in XPL that can support this observation. **[0.2 pts]**

3. Note the large, high relief mineral. What texture name would you give these grains. Notice also that the platy minerals are "deflected" around it and that there are other minerals inside these grains. So, was this mineral present before this rock was metamorphosed or grew during metamorphism? **[0.2 pts]**

Thin Section Sketch (Color)
PPL / XP
Label Grains **[0.15 pts]**



4. **Complete the following table**. These should consider both hand sample (hs) and thin section observations (they should be pretty consistent, especially relative size and abundance). The abundance must equal 100% for all listed species. **[1.0 pt]**

	Mineral 1	Mineral 2	Mineral 3	Mineral 4	Mineral 5	Mineral 6
Name						
Size						
Other Observaions						
Color & Form in HS						
Abundance (%)						

5. Did this rock undergo regional or contact metamorphism? Why? **[0.2 pts]**

6. What is a likely protolith for this rock? Why? **[0.1 pts]**

7. Rock Name: _____ **[0.2 pts]**

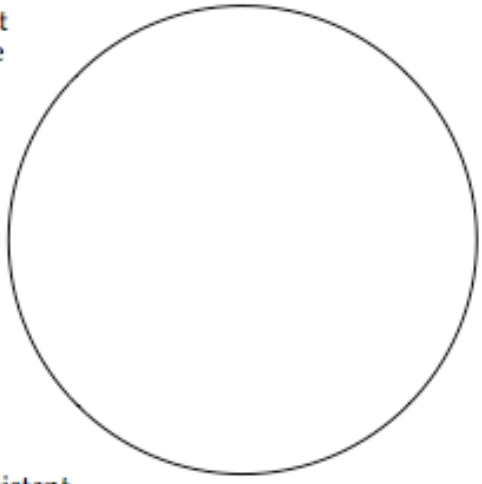
2.25 points

Metamorphic Rock Identification (Lab 11)

Sample # **L387** Name:_____

1. Is this sample **foliated** or **non-foliated**? If foliated, is it a **slate**, **phyllite**, **schist**, or **gneiss**? **[0.2 pts]**

Thin Section Sketch (Color)
PPL / XP
Label Grains **[0.15 pts]**



2. What can you say about the grain size distribution of the abundant mineral with low birefringence in this sample? Are they all about the same, two distinct size groups, or a wide range in sizes? **[0.2 pts]**

3. Based on your hand sample and thin section observations, what mineral dominates the white portion of the hand sample, and what mineral dominates the dark portions? **[0.2 pts]**

4. **Complete the following table**. These should consider both hand sample (hs) and thin section observations (they should be pretty consistent, especially relative size and abundance). The abundance must equal 100% for all listed species. **[1.0 pt]**

	Mineral 1	Mineral 2	Mineral 3	Mineral 4	Mineral 5	Mineral 6
Name						
Size						
Other Observaions						
Color & Form in HS						
Abundance (%)						

5. Did this rock undergo regional or contact metamorphism? Why? **[0.2 pts]**

6. What are likely protoliths for this rock (there can be more than one)? Why? **[0.2 pts]**

7. Rock Name: _____ **[0.2 pts]**

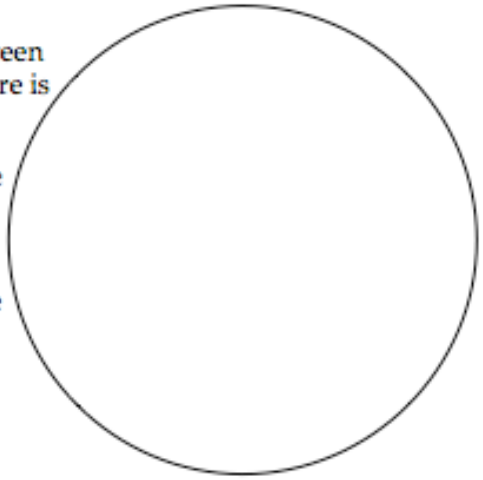
2.25 points

Metamorphic Rock Identification (Lab 11)

Sample # **L404** Name:_____

1. Is this sample **foliated** or **non-foliated**? If foliated, is it a **slate**, **phyllite**, **schist**, or **gneiss**? **[0.2 pts]**

Thin Section Sketch (Color)
PPL / XP
Label Grains **[0.25 pts]**



2. Look closely at the contacts between the grains of the dominant mineral in the thin section of this rock. Notice how the contacts between 3 grains meet at a triple junction defining 3 angles of 120°. This feature is called *granoblastic texture*. Note also that the grains do not display undulose extinction. Both of these features indicate that these minerals crystallized in a low strain environment. Be sure to include the granoblastic texture in your sketch.

3. What can you say about the grain size distribution in this sample? Are they all about the same, two distinct size groups, or a wide range in sizes? **[0.2 pts]**

4. **Complete the following table**. These should consider both hand sample (hs) and thin section observations (they should be pretty consistent, especially relative size and abundance).
The abundance must equal 100% for all listed species. **[1.0 pt]**

	Mineral 1	Mineral 2	Mineral 3	Mineral 4	Mineral 5	Mineral 6
Name						
Size						
Other Observaions						
Color & Form in HS						
Abundance (%)						

5. Did this rock undergo regional or contact metamorphism? Why? **[0.2 pts]**

6. What is a likely protolith for this rock? Why? **[0.2 pts]**

7. Rock Name: _____ **[0.2 pts]**

/2.25 points